آشنایی با ویژگی های فیزیکی، شیمیایی و بیولوژیکی

آب و فاضلاب و استانداردهای مربوطه

ویژگی های فیزیکی آب

WATER QUALITY PARAMETERS

- Physical Water Quality
  - Turbidity
  - Total Solids (TS) and Suspended Solids (SS)
  - Colour
- Chemical Water Quality
  - Hydrogen Ion Concentration and pH
  - Total Dissolved Solids
  - Alkalinity
  - Hardness
  - Fe and Manganese
  - Etc.

PHYSICAL WATER QUALITY
TOTAL SOLIDS (TS) AND SUSPENDED SOLIDS (SS)

- Total Solids in water and wastewater include suspended solids (> about 1.0 microns) and dissolved solids (< 0.001 micron in size). (In the LAB Course)
- Suspended Solids include colloids (0.001 – 1 microns), supra-colloids (1 – 100 microns) and settleable solids (> 100 microns). (In the LAB Course) ذرات قابل تع نشینی

PHYSICAL WATER QUALITY
TOTAL SOLIDS (TS) AND SUSPENDED SOLIDS (SS)

ذرات فرار

- Volatile Solids (volatile SS, VSS and total volatile solids TVS)

احتراق

  - VS are determined by igniting the residue on evaporation of the filtered solids at 500 ° C ± 50 ° C for 15 – 20 minutes in an electric muffle furnace.
  - It is used as a measure of the organic content.
- Settleable Solids
  - Measured by the Imhoff Cone.

PHYSICAL WATER QUALITY TURBIDITY

- Turbidity is a physical characteristic of water that makes water appears cloudy.
- Turbidity is caused by colloidal materials (e.g. clay, silt, metal oxides, micro-organisms, fibers, oils and soaps)
- Turbidity measures the clarity of water containing colloidal material that can not be measured by suspended solids measurement, and of water that contains low level of SS.
- Measured by Turbidimeter (nephelometer)
- **Units:**

  Nephlometric Turbidimeter

PHYSICAL WATER QUALITY COLOR

- Types
  - True color: caused by dissolved solids
  - Apparent color: caused by suspended solids and includes true color.
- Sources
  - Natural Minerals (e.g. iron and manganese brown and tan color)
  - Decay of Organic Matter (e.g. leaves, woods)
  - Colored industrial wastes (e.g. wastes from textile and dying industries).
- Measurement
  - Visual Comparison with standard platinum-cobalt solution.
  - Colorimeters or spectrophotometers.
  - True Color Unit (TCU).

رنگ برنزه

منسوجات (پارچه)

CHEMICAL WATER QUALITY
HYDROGEN ION CONCENTRATION AND PH

- Water (H_2O) dissociate slightly to H^+ and OH^-:

$$H_2O \leftrightarrow H^+ + OH^-$$

آب خالص

- The Hydrogen ion concentration [H^+] for pure water at 25 ^oC is about 10^{-7} mol/L (molar concentration), and the hydroxide ion concentration [OH^-] is 10^{-7} mol/L.

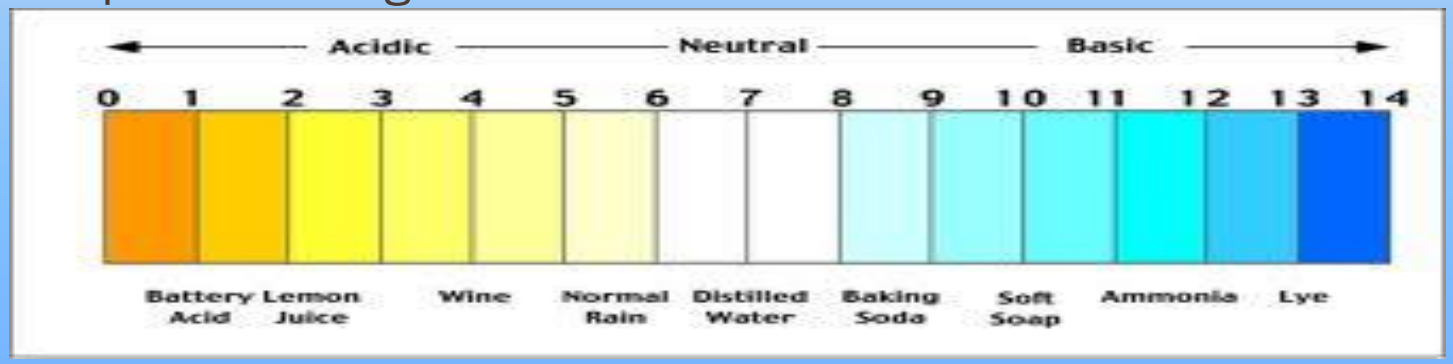
$$[H^+] + [OH^-] = 10^{-14}$$

$$pH + pOH = 14$$

CHEMICAL WATER QUALITY
HYDROGEN ION CONCENTRATION AND PH

- pH = - log $[H^+]$ = negative logarithm of hydrogen ion concentration.
- if $[H^+] = 10^{-7}$ then pH= 7 and pOH = 7
- pH is a measure of the hydrogen ion concentration and is an indicator of the strength of an acid or base.

  Note: pH does not measure total alkalinity or total acidity of water.
- The pH scale ranges from 0 to 14



- Adding an acid to water causes additional H+ ion to be released so that the H+ ion concentration goes up and the pH value goes down:

  HCL ----------> $H^+ + Cl^-$

CHEMICAL WATER QUALITY
HYDROGEN ION CONCENTRATION AND PH

- Strong inorganic acids (e.g. HCl, H_2SO4) ionize completely in water, and the concentration of H^+ then equals the molar concentration of the acid.
- Weak acids (e.g. Acetic acid, hypochlorous acid (HClO) and inorganic acids are poorly ionized in water.
- Measurement by pH meter with an electrode.
- Significance of pH
  - Important in chemical and biological treatment processes of water and wastewater (pH must be controlled within an appropriate range)
  - Important in corrosion control.

CHEMICAL WATER QUALITY
TOTAL DISSOLVED SOLIDS (TDS)

- Dissolved Solids are the solids that can be recovered from water by evaporating the water after filtering the suspended solids (they are less than 0.001 micron in size)
- Method of Measurement
  - Filtration

    $$TDS = TS - SS$$

  - Conductivity can be used as a rough measure of the concentration of the total dissolved salts (Conductivity Meter), units 1.0 µS/m = 10 µmhos/cm

    Conductivity of tap water = 70 – 150 µS/m

CHEMICAL WATER QUALITY ALKALINITY

- Water alkalinity is a measure of the water ability to resist changes in pH when a strong acid is added (i.e. Ability of water to neutralize acids; buffering capacity of water).
- Water alkalinity results from the presence of bicarbonate (HCO_3^-), carbonate (CO_3^{--}), and hydroxide (OH^-) of elements such as calcium, magnesium, sodium, potassium or ammonia.
- These compounds originate from
  - Chemical compounds dissolved from rocks and soil, and
  - CO_2 from the atmosphere and microbial decomposition of organic matter.

    $CO_2 + H_2O$ <--> H_2CO_3 carbonic acid <--> $H^+ + HCO_3$
- Measured by titration

CHEMICAL WATER QUALITY ALKALINITY

- Alkalinity of water either high or low has no ill effects on humans.
- Highly alkaline waters are unpalatable (bitter taste)
- $CO_3^{=}$ and HCO_3^{-} alkalinity complex some heavy metals and thus reduces their toxicity
- Highly alkaline water often has a high pH and generally contains high levels of dissolved solids (harmful for water to be used in boilers, food processing and municipal water systems).
- Alkalinity is important for proper chemical treatment of water and wastewater (e.g. Coagulation, softening), and corrosion control.

بی مزہ (طعم تلخ)

انعقاد

CHEMICAL WATER QUALITY HARDNESS

- Hardness is a characteristics of water that prevents that lathering of soap and produces scale in hot water pipes, heaters and other units due to the presence of divalent metallic ions (calcium, magnesium, ferrous ions, manganous ion, and strontium).
- Hardness in water results from the contact with soil and rocks (limestone) in the presence of CO_2
- Types of hardness
  - Carbonate hardness (temporary hardness): caused by the presence of carbonate and bicarbonate of Ca^{++} and Mg^{++}.

    $Ca(HCO_3)_2 \rightarrow CaCO_3 + CO_2 + H_2O$

    $Mg(H\ CO_3)_2 \rightarrow Mg(OH)_2 + 2\ CO_2$
  - Non-carbonate hardness (permanent hardness): caused by the presence of chlorides, sulfate and nitrates of calcium, magnesium, and iron.

CHEMICAL WATER QUALITY HARDNESS

- Calculation Method
  - This method is used when complete chemical analyses are available.
  - Hardness (mg/L as caCO3) $= \frac{M^{++}(mg/L)}{EW \text{ of } M^{++}(g/eq)} \times 50$

    Where M^{++} represents any divalent metallic ion.
  - Example
- EDTA Titri-meteric Method (In LAB Course)

CHEMICAL WATER QUALITY HARDNESS

- Classification of Water According to its Hardness.

Classification	Hardness Level
Soft	≤ 50 mg/L $CaCO_3$
Moderately Soft	50 – 150 mg/L $CaCO_3$
Hard	150 – 300 mg/L $CaCO_3$
Very Hard	> 300 mg/L $CaCO_3$

CHEMICAL WATER QUALITY HARDNESS

- Impact of Hardness
  - Mg hardness associated with SO_4= has laxative effect on persons unaccustomed to it.
  - Excessive hardness is problematic from the economical point of view (scale formation, high soap consumption)
  - Water Softer than 30 – 50 mg/L as $CaCo_3$ tends to be corrosive.

CHEMICAL WATER QUALITY IRON (FE) AND MANGANESE (MN)

- They are present in soil and rocks in insoluble forms (i.e. Ferric oxide, iron sulfide and manganese dioxide).
- Ground waters that are devoid of dissolved oxygen and high of CO_2 content can contain appreciable amounts of fessous ion (Fe^{++}) and manganese ion (Mn^{++}). [Iron ≈ 10 mg/L and Manganese ≈ 2 mg/L].
- Measurements
  - Using colorimeters (adding chemical agent to water)
  - Using Atomic Absorption Spectophotometer.
- Significance of Iron and Manganese
  - Contribute to hardness
  - They are oxidized upon exposure to air causing: metallic taste, staining of clothes and pluming fixture, precipitates in pipes, growth of slime in pipes producing odor and taste problems.

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CHEMICAL WATER QUALITY TRACE METALS

- Trace metals include those metals that are harmful and toxic in relatively small amounts.
- The main source of these metals is the discharges of domestic, agricultural, or industrial waste water.
- Examples of trace metals: arsenic, cadmium, chromium, mercury, lead, silver and barium. سرب و نقره
- Measurement: Atomic adsorption spectophotometer.

CHEMICAL WATER QUALITY NITROGEN

- Nitrogen compounds
  - Inorganic: Ammonia NH_3, Nitrite NO_2, Nitrate NO_3
  - Organic: Protein, amino acids
- Main Sources
  - Discharge of domestic, agricultural (fertilizers), industrial waste water.
  - Animal wastes
  - Decomposition of dead plants, animal and oragincs by micro-oragnisms

    Protein → Amino Acid→ Ammonia→ Nitrite→ Nitrate

CHEMICAL WATER QUALITY NITROGEN

- Significance of Nitrogen Compounds
  - Ammonia is very toxic to aquatic life

    $NH_3 + H^+ <- -> NH_4^+$

    Decreasing the pH will shift the reaction to the right (NH_4^+). Ammonium ions (NH_4^+) are highly soluble in water but are not toxic.
  - Oxidation of NH_3, NO_2^-, NO_3^-, and NH_4^+ by micro-organisms lowers dissolved oxygen concentration in water causing harm to aquatic life.
  - Presence of nitrogen compounds along with phosphorus in water bodies their eutrophication (excessive growth of algae and green plants) which in turn:
    - Lowers dissolved oxygen level in water
    - Changes color of water
    - Changes taste and odor of water
    - Makes water bodies unfit for recreational purposes.

CHEMICAL WATER QUALITY NITROGEN

- Significance of Nitrogen Compounds
  - Drinking of water with high nitrate content (NO_3^-) causes:
    - Blue-baby disease in infants (methemoglobinemia): bacteria in infants' intestines (less than 6 month old) reduce NO_3^- to NO_2^- that oxidizes hemoglobin (containing Fe^{++}) to methemoglobin (containing Fe^{+++}), which is incapable of transporting O_2 in the blood stream. This causes a bluish discoloration of infants, and serious health problems and even death.
  - Nitrite (NO_2^-) can combine with various amines in the gastrointestinial tract to form nitosamines, many of which are known to be carcinogenic. Nitrite is used in cured meat (hotdogs, prepared meats) to retard bacterial growth.

CHEMICAL WATER QUALITY NITROGEN

- Measurement
  - Ammonia Nitrogen (NH3-N)
    - By titration method
  - Organic Nitrogen
    - Digestion then measure NH4+
    - Total Kjeldahl Nitrogen (TKN) = organic nitrogen + ammonia nitrogen
  - Nitrate-Nitrogen and Nitrite-Nitrogen
    - By Colorimetrical method.

CHEMICAL WATER QUALITY ORGANIC ATTER

- Organic compounds are composed mainly of carbon and hydrogen along with other elements such as oxygen, nitrogen, phosphorus, and sulfur.
- Organics can be classified on the basis of their origin into
  - Natural organics (e.g. plants and animal tissues, human feces)
  - Synthetic organics (e.g. plastics, rubber)

پساب انسانی

- Based on their microbial degradation, organics can be:
  - Biodegradable
  - Non-biodegradable
- Organics in wastewater
  - Organic s in domestic wastewater include carbohydrates, proteins, fats and oils, and synthetic organics.

چربی

  - About 20% to 40% of the organics in sanitary wastewater is non-biodegradable.

CHEMICAL WATER QUALITY ORGANIC MATTER

- Measurement of Organic Concentration in Water
  - Methods to measure concentrations> 1 mg/L
    - Biochemical oxygen demand, BOD
    - Chemical oxygen demand, COD
    - Total organic carbon, TOC
  - Methods to measure concentrations 10^{-12} to 10^{-3} mg/L
    - Gas chromatograph, GC
    - Mass spectroscopy (طیف سنجی جرمی), MS

CHEMICAL WATER QUALITY BIOCHEMICAL OXYGEN DEMAND

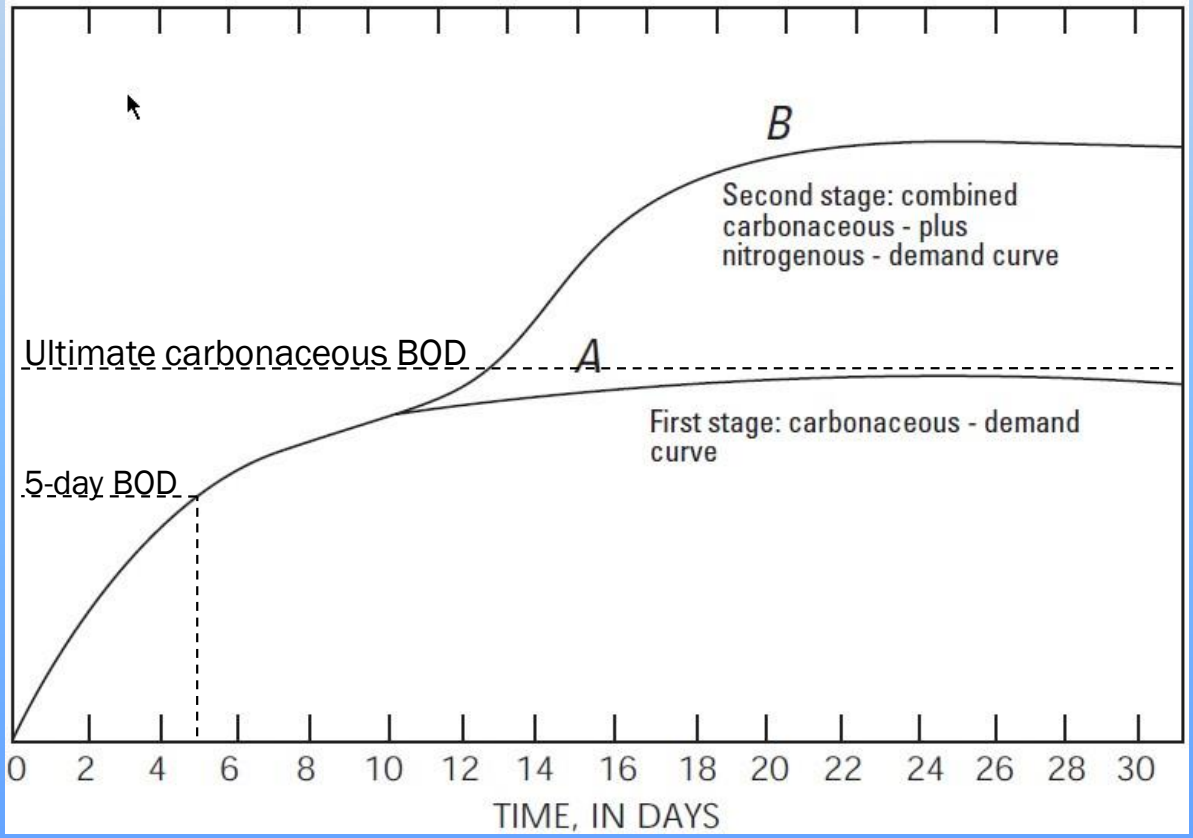
- BOD is the amount of oxygen required (consumed) by microorganisms to biologically degrade organic matter in a water sample under aerobic conditions during a 5-day period at 20 ^{o}C.

  Organics + Microorganisms + O_2 → CO_2 + H_2O + new cells

- BOD is expressed in mg O_2/L of water sample (mg/L).
- BOD is used to:
  - Measure the organic strength of water/wastewater.
  - Determine the relative oxygen requirements for the biological treatment of wastewater.

CHEMICAL WATER QUALITY BIOCHEMICAL OXYGEN DEMAND

- The BOD Curve



CHEMICAL WATER QUALITY BIOCHEMICAL OXYGEN DEMAND

- The Shape of BOD curve can be expressed mathematically as:

$BOD_t = BOD_{ultimate} (1 - e^{-tK})$

$BOD_t = BOD_{ultimate} (1 - 10^{-tk})$

$BOD_5 = BOD_{ultimate} (1 - e^{-5K})$

$BOD_5 = BOD_{ultimate} (1 - 10^{-5k})$

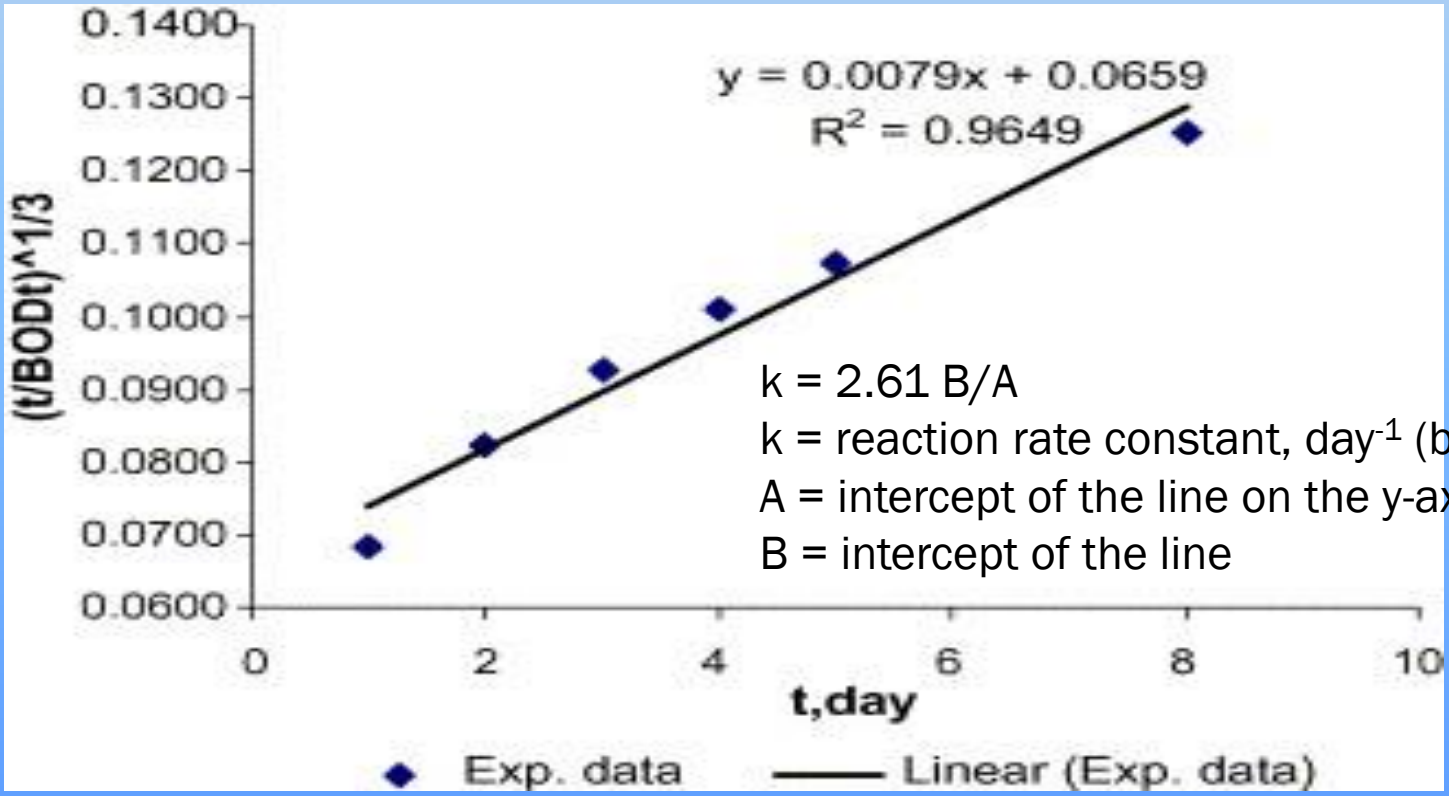
Note:

  - K (base e) = 2.303 k (base 10)

CHEMICAL WATER QUALITY BIOCHEMICAL OXYGEN DEMAND

- Thomas Method to Determine k (base 10)

Plot values of $[t/BOD_t]^{1/3}$ as ordinate (y) against time (t) as abscissa (x).



k = 2.61 B/A

k = reaction rate constant, day^{-1} (base 10)

A = intercept of the line on the y-axis

B = intercept of the line

CHEMICAL WATER QUALITY BIOCHEMICAL OXYGEN DEMAND

- Remarks on K (the reaction-rate constant)
  - K determines the speed of the biological reaction.
  - K is function of type of waste, temperature, ability of micro-organisms.
  - Temperature: K value increases with increasing temperature because micro-organisms are move active at higher temperatures

    $K_T = K_{20}\,\Theta^{(T-20)}$ $\Theta = 1.047$
  - Types of waste : simple compunds such as sugar are easily degraded by micro-organisms and have high K values. Complex compounds such as phenols are difficult to degrade and have low K values
- Example

  In a BOD determination, 40 mL of wastewater containing 2 mg/L DO, are mixed with 260 mL of dilution water containing 9 mg/L of DO. After 5 days of incubation the DO content of the mixture is 2.74 mg/L. Estimate the BOD5 of the wastewater.
- Example

  For the wastewater of the previous example, estimate the oxidation rate of the waste if the ultimate BOD is 100 mg/L. Estimate also the remaining oxygen demand after 5 days.

CHEMICAL WATER QUALITY CHEMICAL OXYGEN DEMAND

- COD is the amount of oxygen required to chemically oxidize organics in water.
- Measurement
  - The Dichromate Reflux Method.
- For domestic wastewater, COD>BOD_5 because:
  - COD includes both biodegradable and non-biodegradable organics.
  - $BOD_5 \neq BOD_{ultimate}$ sfs
  - The BOD/COD ratio varies from 0.4 to 0.8 for raw sanitary wastewater. (فاضلاب بهداشتی خام)

CHEMICAL WATER QUALITY CHEMICAL OXYGEN DEMAND

منظور از این شاخص تعیین مقدار کل مواد آلی موجود در آب است. این شاخص هم معرف مواد آلی قابل تجزیه و هم غیرقابل تجزیه توسط باکتری‌ها می‌باشد، بنابراین با تقریب خوبی می‌تواند معرف ناخالصی‌های آلی نمونه باشد. آزمایش COD به سهولت و در زمان کمی (نزدیک به ۳ ساعت) قابل انجام می‌باشد بنابراین با توجه به همبستگی بین غلظت BOD و COD، عموماً بجای آزمایش BOD که چند روز به طول می‌انجامد، آزمایش COD جهت تخمین BOD نهایی مورد استفاده قرار می‌گیرد.

CHEMICAL WATER QUALITY TOTAL ORGANIC CARBON (TOC)

- TOC measures the organically bound carbon in the waste.
- Measurement
  - Using a TOC analyzer.
- For raw domestic wastewater:

BOD ≈ 220 mg/L COD ≈ 500 mg/L TOC ≈ 160mg/L

CHEMICAL WATER QUALITY TOTAL ORGANIC CARBON (TOC)

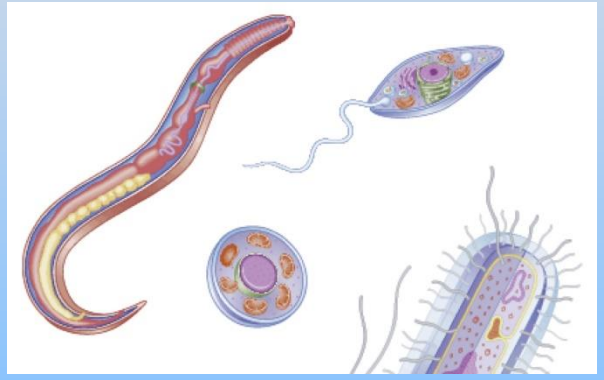
اندازه‌گیری کل مواد آلی آب معمولاً به کمک آزمایش اکسیژن مورد نیاز شیمیایی (COD) یا مقدار کل کربن آلی (TOC) انجام می‌شود. در نمونه‌های آب با سوزاندن نمونه و در نتیجه تبدیل کربن به دی‌اکسید کربن که قابل اندازه‌گیری می‌باشد، می‌توان تقریب خوبی از TOC آب به دست آورد. برای به دست آوردن مقدار مواد آلی غیرقابل تجزیه باید BOD را از COD یا TOC کم کرد. کمیت و کیفیت ترکیبات خاص آلی به کمک روش‌هایی چون کروماتوگرافی گازی قابل اندازه‌گیری است.

MICROBIOLOGICAL WATER QUALITY

- Pathogens: disease causing microorganisms
- Sanitary wastewater is an ideal environment for microorganisms (MOs) because it is rich in the organic and inorganic nutrients needed for their growth.
- Most of these MOs are harmless, but sanitary wastewater may also contain pathogens from the excreta of people with infectious diseases that can be transmitted by contaminated water.

MICROBIOLOGICAL WATER QUALITY

- MOs found in water and wastewater include:



Protozoa (10 – 300 µm)

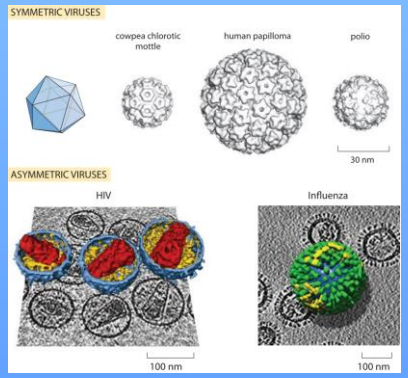
Bacteria

Algae (single cells to visible branched forms)

Fungi (yeasts and mold)

قارچ (مخمرها و کپک)

Worms (herminths)



Viruses (20 – 100 nanometers)

MICROBIOLOGICAL WATER QUALITY

- Waterborne Diseases روده ایی
  - Diseases transmitted by water are almost of intestine (enteric) origin.
  - Bacterial Diseases
    - Cholera (وبا)
    - Dysentery (اسهال خونی)
    - Typhoid
    - Gastroenteritis or diarrheal (E-coli) (اسهال)
  - Protozoan Diseases
    - Amebic dysentery (اسهال خونی آمیبی)
    - Giardiasis
  - Helminthic Diseases (بیماری های کرمی)
    - Bilharziasis
    - Ascariasis
    - Hookworm (کرم قلاب دار)
  - Viral Diseases
    - Infectious hepatitis (type A) (هپاتیت عفونی)
    - Meningitis and heart anomalies
    - Diarrheal (اسهال)

MICROBIOLOGICAL WATER QUALITY

- Indicator Organisms for Water Quality
  - Testing water for pathogens is not feasible because:
    - The absence of pathogens does not mean that others are not present.
    - Pathogens present in polluted water are few and therefore are difficult to isolate and identify.
  - Coliform bacteria or coliforms (non-pathogens bacteria) inhibit the intestines in large numbers and always present in faeces together with any pathogens, are used as indicators of faecal contamination.
  - Some genera of the coliform bacteria are not faecal origin but grow and reproduce on organic matter outside the intestines of humans and animals.
  - The term Total Colifom used in laboratory testing referring to all coliform bacteria from faeces, soils or other origin.
  - The term Faecal Coliform refers to coliform bacteria originating from human or animal faeces.

MICROBIOLOGICAL WATER QUALITY

- Enumeration of Colifrom
  - The Multiple-Tube Fermentation (تخمیر) Technique (the most probable number, MPN)
    - It involves three steps (gas formation within 48 hr at 35C):
      - The presumptive test: the ability of coliform bacteria to ferment lactose broth تست پیش فرض :توانایی باکتری های **کولیفرم** برای تخمیر لاکتوز مایع
      - The confirmed test: growing cultures of coliforms from presumptive test on a medium that suppresses the growth of other bacteria
      - The completed test: the ability for the coliform growth in the conifrmed test to agin ferment lactose broth
  - The Membrane Filter Technique (MF)

MICROBIOLOGICAL WATER QUALITY

- The Membrane-Filter Technique:
  - The test steps are:
    - Filter certain amount of water sample (e.g. 100 mL) under vacuum through a membrane filter,.
    - Place the filter in a plastic petri dish containing the growth medium and incubate at 35°C for 24 hours for total coliforms and at 44.5oC for 24 hr for fecal coliforms. [Medium for total coliform: M-Endo, for fecal coliform: M-FC]
    - Count the number of colonies. A typical coliform colony is pink to dark red with green metallic surface sheen.

Colifrom density (colony/100 mL) =

(coliform colonies counted/mL sample filtered) x 100

MICROBIOLOGICAL WATER QUALITY

- Number of colonies: a range of 20 – 200 colonies is preferred. But for water of good quality (e.g. tap water), disregard the lower limit of 20 colonies.
- Sample Size: governed by the expected bacterial density.
- Standard volume for drinking water: 100 mL
- Main advantages of MF technique over the MPN:
  - The MF enables large volumes of samples to be examined
  - The MF gives a direct count of coliforms rather than an a statistical estimate.
  - The MF is faster than the MPN (within 24 hours).

MICROBIOLOGICAL WATER QUALITY

- Example

  The MF technique was used to test a drinking water for coliform group. 50 mL, 25 mL and 10 mL portions were filtered and the counts were 15, 6, 0 coliform colonies, respectively. Calculate the coliform density.

- Example

  The MF technique was used to test polluted water for total coliform. Three different water sample volumes (5 mL, 50 mL, and 500 mL) were filtered through five filter membranes. The colonies counts were as follows:

  5 mL portions: 7, 9, 11, 5, 4

  50 mL portions: 26, 32, 27, 30, 32

  500 ml portions: TNTC (too numerous to conunt) (i.e. > 200 colonies)

  Calculate the coliform density for this water using the mst valid data.